abraded outcrop surfaces is not especially compelling [27]. In abraded spherules, interpreted to be concretions (see below), no relict grain textures are preserved at MI resolution, so that any siliciclastic material remaining within the spherules must be very fine.

Accordingly, we interpret these grains to be derived from reworking of evaporite-cemented basaltic mud (grain sizes < 100 μm, the effective limit of resolution). The production of aeolian evaporitic sands, notably gypsum sands, is well documented in terrestrial playa lake environments (e.g., [32–36]). Evaporitic detritus can be derived from aeolian reworking of evaporite-cemented mud flats or efflorescent crusts that incorporate fine-grained siliciclastic debris. In the case of the Burns formation, the evaporitic sand grains probably are dominated by basaltic mud rather than evaporitic minerals themselves. An important implication of this model is that playa conditions must have been present at about the time of Burns formation deposition in order to provide the source of sand-sized particles.

Chemical constraints suggest that the siliciclastic component of these sedimentary rocks is between approximately 30–50% on an anhydrous basis and is likely concentrated within the grains, although some component of aeolian dust deposited during deposition of the Burns formation itself could also be present [37]. Thus, given that on the order of 35–45% of the sediment mass is composed of various sulfate ± chloride cements [25], a significant fraction of each of the grains is likely to be composed of evaporitic cements.

## 4.2. Provenance of siliciclastic component

Geochemical and mineralogical constraints clearly indicate that the siliciclastic provenance is composed predominantly of basaltic sources (Fig. 2). Although Mössbauer spectra on abraded surfaces indicate about 5–10% pyroxene and, at most, trace levels of olivine, the identification of pyroxene by Mössbauer is not definitive. This spectral feature could represent another octahedrally coordinated Fe(II) phase [27]. Mini-TES "footprints" are much larger than the area exposed by the RAT and so mineralogical determinations by this instrument are difficult to relate unambiguously to abraded outcrop. Nevertheless, dust-corrected mineralogical determinations on outcrop surfaces made by Mini-TES suggest the following non-chemical constituents (in approximate decreasing order): intermediate to high-silica components (modeled as high-Si glass, feldspar and minor sheet silicates), olivine and pyroxene [28]. However, correlating Mini-TES with Pancam images suggests that olivine and pyroxene abundances

are strongly controlled by the presence of wind-blown sand on the outcrop surfaces and thus are likely not intrinsic to the Burns formation. In any case, no mineral has been identified or inferred from spectral data (e.g., quartz, K-feldspar, biotite, amphibole) that is inconsistent with a purely basaltic provenance or its altered derivative.

Characterizing the nature of the basaltic component is not straightforward. Because the mineralogy of chemical constituents is only partially constrained, it is not possible to evaluate the bulk chemistry of siliciclastic components quantitatively. Similarly, evaluating the degree to which siliciclastic material has been altered is difficult because variations in chemical composition that are characteristic of chemical weathering and low temperature alteration (e.g., [12]) cannot be disentangled from possible variations in evaporitic mineralogy. For example, partitioning of Ca, Mg, Fe, Na and K between chemical and non-chemical components is not known with certainty and so it is not possible to "remove" the chemical components through mass balance mixing calculation with any certainty. Even silicon, commonly released as amorphous silica in basalt alteration processes [38], does not necessarily reflect igneous abundances and indeed there is evidence that secondary silica is present (Fig. 2b; also see [25]). Accordingly, we are left with elements Al, Ti, Cr and Ni as most likely to reflect primary provenance relationships. However, it is worth noting that in low pH environments even Al is relatively mobile and that aluminum sulfates can be a common chemical constituent in acid lake and acid alteration environments (e.g., [30]).

Assuming that Al, Ti, Cr and Ni are reflective of the average provenance composition, no known martian basalt is a good match for the siliciclastic component of the Meridiani outcrop. The outcrop is characterized by modest Cr/Ni ratios of about 2 (Fig. 3) and high Ni abundances (730 ppm average); SNC meteorites and basalts from the other MER site at Gusev crater all have an order of magnitude higher Cr/Ni ratios. Of the two Meridiani igneous rocks analyzed (Bounce Rock and Barberton), only Barberton comes close to the Meridiani outcrops with comparable Cr/Ni ratios and only slightly higher Cr abundances (normalized to Al). However, Meridiani outcrop rocks have $TiO_2/Al_2O_3$ ratios that are more than 50% higher than Barberton and so the match is not exact. Chromium and nickel are highly susceptible to compositional variations associated with igneous fractionation of olivine and spinel and it is notable that many basaltic shergottites are cumulates. Accordingly, the basaltic provenance of the Meridiani